REDUCTION OF HARMONIC USING PSO TECHNIQUE FOR GRID CONNECTED PHOTOVOLTAIC SYSTEM

HONG CHEONG HENG



UNIVERSITI TEKNOLOGI MALAYSIA

# REDUCTION OF HARMONIC USING PSO TECHNIQUE FOR GRID CONNECTED PHOTOVOLTAIC SYSTEM

HONG CHEONG HENG

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2018

*Specially dedicated*

*to my beloved father, mother, brother.*

## ACKNOWLEDGEMENT

After a long journey of ups and down, at last, the thesis was submitted. I would like to thank to the parents for all the supports, the courage and patience along with this journey. Special appreciation to my supervisor, Dr. Jasrul Jamani Bin Jamian for all the positive vibes and continuous courage and knowledge. I would like to thank to Universiti Teknologi Malaysia for giving me the chance to pursuing the master degree, thank you to all the lecturers for all knowledge and supports. Last but not least, thank you so much to my postgraduate friend for all your support, knowledge and courage.

# ABSTRACT

The use of photovoltaic (PV) system as an alternative energy technology for supplying clean energy become popular nowadays due to the reduction of investment capital cost. However, harmonic produced by the inverter of the PV system has led to power quality issue in the power grid. Therefore, it is highly important to control and reducing the amount of harmonic contributed by the PV. There are many existing modulation technique that had been proposed to minimize the content of the harmonic which include the use of single wave pulse-width PWM, multi-wave PWM, carrier-based PWM, sine-wave PWM and space vector PWM. In this report, a new methodology to eliminate the selective harmonic by using the harmonics elimination PWM (HEPWM) as the modulation scheme of the PV conversion system is proposed. Heuristic based algorithm approach of Modified Particle Swarm Optimization (MPSO) has been deployed in MATLab software to solve the nonlinear transcendental equations of the HEPWM. MPSO algorithm doesn't required a good initial estimation and can be simple to be implemented with a powerful computer. Therefore, the main objective in this study is to determine the optimal switching angles for the multilevel inverter of the PV system. The obtained switching angle is used to control the multilevel inverters in order to synthesize an output stepped voltage waveform with minimum harmonic content. The simulation results show that the specific lower order of harmonics for the inverter can be removed and the overall voltage total harmonic distortion (THD) level can be reduced.

# ABSTRAK

Penggunaan sistem photovoltaic (PV) sebagai teknologi tenaga alternatif untuk membekalkan tenaga bersih menjadi popular pada masa kini disebabkan oleh pengurangan kos modal pelaburan. Walau bagaimanapun, harmonik yang dihasilkan oleh penyongsang mempunyai masalah dengan grid kuasa. Oleh itu, sangat penting untuk mengawal dan mengurangkan jumlah harmonik yang disumbangkan oleh PV. Terdapat banyak teknik modulasi sedia ada yang telah dicadangkan untuk mengurangkan kandungan harmonik yang termasuk penggunaan tunggal gelombang nadi-lebar PWM, pelbagai gelombang PWM, PWM berasaskan kapal pengangkut, PWM sinus gelombang dan ruang vektor PWM. Dalam laporan ini, satu kaedah baru untuk menghapuskan harmonik terpilih dengan menggunakan PWM harmonik penyingkiran (HEPWM) skim modulasi sistem PV penukaran adalah dicadangkan. Heuristik berasaskan pendekatan algoritma Modified Particle Swarm Optimization (MPSO) telah digunakan dalam perisian MATLab untuk menyelesaikan persamaan rohani tak linear HEPWM itu. Algoritma MPSO tidak diperlukan anggaran awal yang baik dan boleh menjadi mudah untuk dilaksanakan dengan sebuah komputer yang berkuasa . Oleh itu, objektif utama dalam kajian ini adalah untuk menentukan sudut pensuisan optimum bagi penyongsang pelbagai peringkat sistem PV. The beralih sudut diperolehi digunakan untuk mengawal penyongsang pelbagai peringkat untuk mensintesis output melangkah bentuk gelombang voltan dengan kandungan harmonik minimum. keputusan simulasi menunjukkan bahawa usaha yang lebih rendah tertentu harmonik untuk penyongsang boleh dikeluarkan dan jumlah tahap voltan keseluruhan herotan harmonik (THD) dapat dikurangkan.

## TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

The increasing demand of photovoltaic (PV) system as a distributed generation connected to the power grid rise the concern of power quality issues in the utility grid. This grid connected PV system uses static inverter to covert dc voltage of the solar panel to a changeable amplitude and frequency output voltage of sinusoidal ac form in order to fulfill the requirements of load. However, this conversation has caused a great amount of current harmonics injected into the power grid when large quantities of inverters were installed in the PV system plant. Hence, it is expected that the harmonic content of each individual PV system plant need to be controlled and minimized before delivery of power to the load.

There are several pulse width modulation (PWM) techniques adopted for the dc-ac inversion, such as single or multi-wave technique, carrier based technique, sine wave technique, space vector technique and the selective harmonic elimination technique. Nevertheless, the most regularly used methods to perform such inversion is the carrier based PWM. Generally, PWM uses a sequence of width modulation pulses to form a sinusoidal ac voltage. With the increased number of pulses toward finite number of pulses, the total harmonic distortion (THD) of load voltage can be decreased. Hence, the amplitude of the output voltage can be controlled by the PWM and the size of filter in the PV system can be reduced for minimization of the harmonic content.

## 1.2 Problem Statement

The widely integration of PV system with the utility power grid has caused the heavily used of inverter in the system. Cascaded multilevel inverter has been commonly selected for the PV system due to the advantages of higher power and without the need of transformer. However, the switching of huge amount of power electronic switches in the cascaded multilevel inverter has initiated high harmonics into the system. The key problem remain encountered in such application is the reduction of THD value in order to meet the IEEE 519 standard.

There are many existing way of harmonics control schemes for the cascaded multilevel inverter, one of which is the Harmonics Elimination PWM (HEPWM) methods. However, solving the non-linear transcendental equations of the HEPWM which describing the harmonics is the foremost difficulties in such techniques. These non-linear equation can be solved by using Newton-Raphson (NR) iterative method, but it is not suitable when a large amount of switching angles are involved, in which it required an initial guess close to the solution. Besides that, resultant theory can also be applied to solve the transcendental equations by converting them into equivalent set of polynomial equations. However, solving the polynomial equations is very difficult for removal of high number of harmonic.

Lately, heuristic methods such as genetic algorithm, particle swarm optimization, ant colony optimization, bee algorithm and etc. have been commonly applied for eliminating of the selective harmonic in the cascaded multilevel inverter. Nevertheless, an effective and superior convergence technique is certainly desired to solve the complicated harmonic problem by the cascaded multilevel inverter used in the PV system.

## 1.3 Objectives of Project

The main objective of the project is to analyze on the outcome of the harmonic content produced by the PV system with implementation of the Modified Particle Swarm Optimization (MPSO) method in generating the optimal switching angles for the seven level cascaded multilevel inverter.

Following are the objectives that need to be achieved for the study:-

1. To implement the HEPWM based technique of MPSO algorithm in MAT Lab software to solve the non-linear transcendental equations.

2. To identify the optimal switching angles for the seven level cascaded multilevel inverter of the PV system.

3. To eliminate / minimize the 3th and 5th harmonic order component of the seven level cascaded multilevel inverter and further reduce the THD of the PV System.

## 1.4 Scope of Project

This study focus on the modeling and simulation of the seven level cascaded multilevel inverter with MPSO algorithm for the PV system using MATLab / Simulink software. As far as this study is concerned, only third and fifth harmonics order are to be eliminated using the MPSO algorithm in order to reduce the overall THD of the PV system. The optimal switching angles and THD results obtained from the simulation are then analyzed in relation to the manual calculation.

## 1.5 Significance of Project

Problems with regards to the harmonics in the power system are infrequent but it is possible for a number of unwanted effects to happen. The presence of high levels of harmonics distortion in the power systems can give rise to several issues such as overheating of transformers, motors, lines and cables. Particularly, the third harmonic order upsurges zero sequence current and consequently increases the current in neutral conductor. Moreover, it can cause interference to the communication system and result in failure of equipment. Besides that, inaccurate readings on meters and incorrect operation of protection relays due to the existence of harmonics have affected the power operator with high economic losses.

Therefore, it is highly important to further improve on the method with regards to the reduction of harmonic due to the inversion process in the grid connected PV system.

## REFERENCES

[1] Ilhami Colak, Ersan Kabalci, Ramazan Bayindir, Review of multilevel voltage source inverter topologies and control schemes, In Energy Conversion and Management, Volume 52, Issue 2, 2011, Pages 1114-1128, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2010.09.006.

[2] Venkatachalam Kumar Chinnaiyan, Jovitha Jerome, J. Karpagam, An experimental investigation on a multilevel inverter for solar energy applications, In International Journal of Electrical Power & Energy Systems, Volume 47, 2013, Pages 157-167, ISSN 0142-0615, https://doi.org/10.1016/j.ijepes.2012.10.025.

[3] M. Valan Rajkumar, P.S. Manoharan, A. Ravi, Simulation and an experimental investigation of SVPWM technique on a multilevel voltage source inverter for photovoltaic systems, International Journal of Electrical Power & Energy Systems, Volume 52, November 2013, Pages 116-131, ISSN 0142-0615

[4] Quang-Tho Tran, Anh Viet Truong, Phuong Minh Le, Reduction of harmonics in grid-connected inverters using variable switching frequency, International Journal of Electrical Power & Energy Systems, Volume 82, November 2016, Pages 242-251, ISSN 0142-0615.

[5] Krismadinata, Nasrudin Abd Rahim, Hew Wooi Ping, Jeyraj Selvaraj, Elimination of Harmonics in Photovoltaic Seven-level Inverter with Newton-raphson Optimization, Procedia Environmental Sciences, Volume 17, 2013, Pages 519-528, ISSN 1878-0296.

[6] Khaled El-Naggar, Tamer H. Abdelhamid, Selective harmonic elimination of new family of multilevel inverters using genetic algorithms, Energy Conversion and Management, Volume 49, Issue 1, January 2008, Pages 89-95, ISSN 0196-8904

[7] Shimi Sudha Letha, Tilak Thakur, Jagdish Kumar, Harmonic elimination of a photo-voltaic based cascaded H-bridge multilevel inverter using PSO (particle swarm optimization) for induction motor drive, Energy, Volume 107, 15 July 2016, Pages 335-346, ISSN 0360-5442

[8] Ş. G. Roşu, C. Rădoi, A. Florescu, P. Guglielmi and M. Pastorelli, "The analysis of the solutions for harmonic elimination PWM bipolar waveform with a specialized differential evolution algorithm," 2012 13th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), Brasov, 2012, pp. 814-821.

[9] A. Kavousi, B. Vahidi, R. Salehi, M. K. Bakhshizadeh, N. Farokhnia and S. H. Fathi, "Application of the Bee Algorithm for Selective Harmonic Elimination Strategy in Multilevel Inverters," in IEEE Transactions on Power Electronics, vol. 27, no. 4, pp. 1689-1696, April 2012.

[10] M. H. Etesami, N. Farokhnia and S. Hamid Fathi, "Colonial Competitive Algorithm Development Toward Harmonic Minimization in Multilevel Inverters," in IEEE Transactions on Industrial Informatics, vol. 11, no. 2, pp. 459-466, April 2015.

[11] M. Mythili and N. Kayalvizhi, "Harmonic minimization in multilevel inverters using selective harmonic elimination PWM technique," 2013 International Conference on Renewable Energy and Sustainable Energy (ICRESE), Coimbatore, 2013, pp. 70-74.

[12] Abdul Moeed Amjad, Zainal Salam, A review of soft computing methods for harmonics elimination PWM for inverters in renewable energy conversion systems, Renewable and Sustainable Energy Reviews, Volume 33, May 2014, Pages 141-153, ISSN 1364-0321

[13] N. Farokhnia, S. H. Fathi, R. Salehi, G. B. Gharehpetian and M. Ehsani, "Improved selective harmonic elimination pulse-width modulation strategy in multilevel inverters," in IET Power Electronics, vol. 5, no. 9, pp. 1904-1911, November 2012.

[14] M. Hajizadeh and S. H. Fathi, "Selective harmonic elimination strategy for cascaded H-bridge five-level inverter with arbitrary power sharing among the cells," in IET Power Electronics, vol. 9, no. 1, pp. 95-101, 1 20 2016

[15] T.R. Sumithira, A. Nirmal Kumar, Elimination of Harmonics in Multilevel Inverters Connected to Solar Photovoltaic Systems Using ANFIS: An Experimental Case Study, Journal of Applied Research and Technology, Volume 11, Issue 1, February 2013, Pages 124-132, ISSN 1665-6423

[16] K. Ganesan, K. Barathi, P. Chandrasekar, D. Balaji, Selective Harmonic Elimination of Cascaded Multilevel Inverter Using BAT Algorithm, Procedia Technology, Volume 21, 2015, Pages 651-657, ISSN 2212-0173

[17] Mohamed S.A. Dahidah, Vassilios G. Agelidis, Single-carrier sinusoidal PWM-equivalent selective harmonic elimination for a five-level voltage source converter, Electric Power Systems Research, Volume 78, Issue 11, November 2008, Pages 1826-1836, ISSN 0378-7796

[18] Krismadinata, Nasrudin Abd Rahim, Hew Wooi Ping, Jeyraj Selvaraj, Elimination of Harmonics in Photovoltaic Seven-level Inverter with Newton-raphson Optimization, Procedia Environmental Sciences, Volume 17, 2013, Pages 519 – 528, ISSN 1878-0296

[19] P. Palanivel and S. S. Dash, "Analysis of THD and output voltage performance for cascaded multilevel inverter using carrier pulse width modulation techniques," in IET Power Electronics, vol. 4, no. 8, pp. 951-958, September 2011.

[20] S. Debnath and R. N. Ray, "Harmonic elimination in multilevel inverter using GA and PSO: A comparison," Electrical, Electronics and Computer Science (SCEECS), 2012 IEEE Students' Conference on, Bhopal, 2012, pp. 1-5.

[21] Mohamed S.A. Dahidah, Vassilios G. Agelidis, Machavaram V. Rao, Hybrid genetic algorithm approach for selective harmonic control, Energy Conversion and Management, Volume 49, Issue 2, February 2008, Pages 131-142, ISSN 0196-8904.

[22] Erkan Deniz, Omur Aydogmus, Zafer Aydogmus, Implementation of ANN-based Selective Harmonic Elimination PWM using Hybrid Genetic Algorithm-based optimization, Measurement, Volume 85, May 2016, Pages 32-42, ISSN 0263-2241

[23] W. Zhang, F. Guo, T. Song, X. Meng and Q. Zhang, "On specific harmonic elimination PWM of inverter based on genetic algorithm," 2016 35th Chinese Control Conference (CCC), Chengdu, 2016, pp. 9207-9211.

[24] B. Cao and L. Chang, "A variable switching frequency algorithm to improve the total efficiency of single-phase grid-connected inverters," 2013 Twenty-Eighth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), Long Beach, CA, 2013, pp. 2310-2315.

[25] X. Mao, R. Ayyanar and H. K. Krishnamurthy, "Optimal Variable Switching Frequency Scheme for Reducing Switching Loss in Single-Phase Inverters Based on Time-Domain Ripple Analysis," in IEEE Transactions on Power Electronics, vol. 24, no. 4, pp. 991-1001, April 2009.

[26] K. L. Shi and Hui Li, "Optimized PWM strategy based on genetic algorithms," in IEEE Transactions on Industrial Electronics, vol. 52, no. 5, pp. 1458-1461, Oct. 2005.

[27] K. Sundareswaran, K. Jayant and T. N. Shanavas, "Inverter Harmonic Elimination Through a Colony of Continuously Exploring Ants," in IEEE Transactions on Industrial Electronics, vol. 54, no. 5, pp. 2558-2565, Oct. 2007.

[28] T. Shindo, T. Kurihara, H. Taguchi and K. Jin'no, "Particle swarm optimization for single phase PWM inverters," 2011 IEEE Congress of Evolutionary Computation (CEC), New Orleans, LA, 2011, pp. 2501-2505.

[29] G. Nageswara Rao, P. Sangameswara Raju, K. Chandra Sekhar, Harmonic elimination of cascaded H-bridge multilevel inverter based active power filter controlled by intelligent techniques, In International Journal of Electrical Power & Energy Systems, Volume 61, 2014, Pages 56-63, ISSN 0142-0615

[30] Abdul Moeed Amjad, Zainal Salam, Ahmed Majed Ahmed Saif, Application of differential evolution for cascaded multilevel VSI with harmonics elimination PWM switching, In International Journal of Electrical Power & Energy Systems, Volume 64, 2015, Pages 447-456, ISSN 0142-0615